RAILWAY GAUGES.

SEYMOUR.

A REVIEW

OF THE

THEORY OF NARROW GAUGES

AS APPLIED TO

MAIN TRUNK LINES OF RAILWAY.

BY SILAS SEYMOUR,
GENERAL CONSULTING ENGINEER.

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RAILWAY GAUGES.

LETTER FROM MR. MARSHALL O. ROBERTS.

TEXAS PACIFIC RAILROAD COMPANY,
OFFICE, CORNER WARREN AND WEST STREETS,
NEW YORK, *Sept.* 23, 1871.

HON. SILAS SEYMOUR,
20 *Nassau street, New York.*

MY DEAR SIR,—I have the honor to send you herewith, the report of our Chief Engineer, General Buell, on the subject of narrow gauges, which is of deep interest to me as the President of the Texas Pacific Railroad, a *great trunk line.*

Before deciding so important a matter as the adoption of a gauge for our road, I feel the necessity of obtaining all the information that can possibly be procured on this subject; and knowing your great experience whilst acting as State Engineer of New York, as Chief Engineer of the N. Y. and Erie Railroad, and other prosperous enterprises, and as Consulting Engineer of the Union Pacific Railroad, I am induced to solicit your written opinion, as to whether a first-class railroad, of equal speed, comfort to passengers, and capacity for freight, with those possessed by the gauges now in general use, can be built upon a narrow gauge; and if so, what gauge would you recommend?

By giving me your views, at your earliest convenience, you will confer a great favor on,

Yours very truly,

MARSHALL O. ROBERTS.

A REVIEW

OF THE

NARROW GAUGE THEORY.

MR. SEYMOUR'S REPLY.

No. 20 Nassau Street,
New York, *Oct. 16th*, 1871.

Dear Sir,—Having received your communication of the 23d ultimo, and the accompanying report of your Chief Engineer, during a somewhat protracted stay in Canada, I have taken the liberty of deferring an answer until my return to my office in this city.

I have read with some care the report of your Chief Engineer, General G. P. Buell, in which he recommends you to adopt a gauge of 3 ft. 6 inches in preference to the 4 ft. 8½ inch, or the 3 ft. gauge, for the Texas Pacific Railroad, extending from the Mississippi Valley to the Pacific Ocean, a distance of about 1,500 miles.

The confidence and earnestness with which your Chief Engineer presents his views and urges his recommendations upon this important subject, show, beyond a doubt, that he is entirely honest in his convictions; and they are therefore entitled to full and fair consideration.

He admits, in his report, that your road will necessarily come in competition with two other grand trunk lines to the Pacific. And he claims that it "already has advantage of the other routes in climate, distance, and economy of construction." He also claims that "the whole subject hinges on the three points—speed (which is time), capacity, and economy;" and that these three points are secured by the adoption of a gauge 1 foot 2½ inches narrower than the gauge of the two other grand competing lines; and which has been in general and successful use throughout the civilized world, during the past half century.

The five following reasons are given for recommending the 3 ft. 6 in. gauge, in preference to the one of 4 ft. 8½ inches:—

"*First.*—That in the construction of the road-bed, etc., the difference will be 30 per cent. of cost of narrow gauge.

"*Second.*—That in the construction of the superstructure the difference will be 45 per cent. of cost of narrow gauge.

"*Third.*—That, with proper construction of rolling stock, a speed of 35 to 45 miles per hour can be attained with perfect safety.

"*Fourth.*—That in the construction of rolling stock the difference will be 50 to 55 per cent. of cost of narrow gauge.

"*Fifth.*—That in the loaded trains of mixed freights and cars, on the 3 ft. 6 in. gauge, the percentage of dead weight to load will be about $\frac{47}{100}$; while in the similar train on the broad gauge road, the percentage of dead weight to load is about $\frac{75}{100}$."

I cannot concur with your Chief Engineer, either in the premises which he assumes, or in the conclusions at which he arrives. Although I will admit, that, assuming everything else to be only equal, if either one of the reasons which he gives can be satisfactorily proven true, he will have gained his case.

The great difficulty, however, will be found to rest in obtaining this satisfactory proof. Take, for example, the construction of the road-bed. I should want to see two parallel lines of equal length, and running over precisely similar ground, constructed, one for the wide, and the other for the narrow gauge, having equal margins for right of way, drainage, slopes, bermes, etc.; and then the difference in cost could be correctly ascertained. But, in the absence of such a test, I cannot admit that there is anything like the difference claimed for this one item, in favor of the narrow gauge.

But as this test never has, and probably never will be made, it only remains to show, by *indirect* or *negative* demonstration, that the proposition cannot be true.

If I understand the proposition (which is stated somewhat ingeniously), it is, that if the narrow gauge road-bed costs $10,000 per mile, the wide one will cost $13,000, the difference being $\frac{3}{13}$, or about 23 per cent.

Perhaps I cannot illustrate my idea of the error better, than by assuming an average mile of grading. masonry, etc., to be fully completed, and ready for the superstructure of the wide gauge; and then, by assuming that a longitudinal section, extending the entire length, and one foot two and a half inches in width, be taken out of the centre, and the sides brought together so as to close up the vacant space. We should then have a perfect road-bed for the narrow gauge; and the question to be determined would be the relation which the longitudinal section, so taken out, bears to the road-bed as left complete for the narrow gauge.

The side slopes of excavations and embankments, which often contain more material than the prism, would, of course, remain the same. The side drains, bermes, and the wings, end walls, and coping of culverts, would also remain the same. If truss-bridging occurs, the entire masonry and superstructure of this would remain the same for both gauges, for the reason that the width of bridges required for passing cars of the widest gauge, has been found none too great to allow of the requisite lateral bracing to keep the bridge in perfect line and adjustment.

The road-bed for the wide gauge is generally fourteen feet in width at grade, but I assume that twelve feet, in good material, is quite ample. By taking out the longitudinal section referred to, there would remain 10 ft. 9½ inches for the narrow gauge road-bed; but reducing this width to ten feet, which, I presume, would be considered as equally ample, and the actual saving in the prism would be only one-sixth, or about 16 per cent. When we add to this reduced prism, the cost of the other elements, which remain the same in both cases: and consider that the shops, station-houses, platforms, etc., etc., would also remain substantially the same, the actual percentage of saving in total cost would become so small, as compared with the amount claimed by your Engineer, that his first reason for recommending the adoption of the narrow gauge loses nearly its entire force.

By the same process of reasoning, the second and fourth reasons given by him, in which he claims that 45 per cent. will be saved in cost of superstructure, and from 50 to 55 per cent. in cost of rolling stock, may be shown to be equally erroneous.

The saving in cost of superstructure, the weight of rails remaining the same, will be only the value of a section, 1 ft. 2½ in. in length, cut from the centre of each tie.

The requisite weight of iron rails is generally supposed to be governed by the weight resting upon each driver of the engine; and as this weight creates the adhesion, and, therefore, governs the power, it follows that, with the same weight of train, it must be equal upon both gauges. If it is claimed that the same amount of tonnage can be hauled with greater economy, by multiplying trains, and using lighter engines, then I maintain that the same principle can be applied upon the wider gauge with equal economy; and, therefore, that no greater weight of rails is required.

The saving in the cost of each car will be only the value of a longitudinal section of 1 ft. 2½ in. taken from the centre of the car, embracing only the top, bottom, and two ends of the body, and the truck frames, and axles below—and, perhaps, a still further trifling deduction on account of the value of materials and labor claimed to be saved in the construction of cars of the proposed diminutive width ; but I claim that the additional number of cars required to transport the same amount of tonnage, or number of passengers, will make the cost quite as much, if not more, for the narrow than for the wider gauge.

I claim also that the cost of locomotives, provided the same amount of power is used, will be no greater for the wide than for the narrow gauge. If there is any difference, it would certainly be in favor of the largest engine.

If these statements are correct, and I have no doubt that they will be found substantially so, there can be no more force in the second and fourth propositions submitted by your Chief Engineer, than there appears to be in the first.

Having had some experience in the construction and equipment of roads, with both the 6 ft. and 4 ft. 8½ in. gauges, the difference in which is slightly greater than that of the two gauges now under discussion, I am not prepared to say, and do not claim that there is actually no difference whatever in their first cost ; but I do say most emphatically that this difference is very largely, although probably inadvertently, overstated by the advocates of this extreme narrow gauge theory.

When, in 1847, this matter was under discussion before the New York & Erie Railroad Company, with reference to the proposed change of gauge from 6 ft. to 4 ft. 8½ inches, I know that this item, of first cost of construction and equipment, did not enter very largly into the argument ; and my recollection is, that it was conceded by the respective advocates of each gauge, that it could not be less than five, nor more than ten, per cent. in favor of the narrow gauge.

The third reason given by your Chief Engineer seems to have very little, if any, application to his argument in favor of the narrow, as against the wide gauge. It seems rather to be introduced for the purpose of showing, or asserting, that a train upon the narrow gauge is capable of attaining as high a rate of speed as is reached upon any first-class railroad. In putting this rate of speed at "35 to 45 miles per hour with perfect safety," I believe him to be in error, because I do not think that such a rate of speed can be adopted with *perfect safety* upon any road, or with any gauge.

With the track in perfect adjustment, and cars of proportionate width and height, I see no reason why an engine of sufficient power will not haul a train with as great speed and safety upon a narrow, as upon a wide gauge. Although I believe it is generally conceded that, in the ordinary condition of our roads and rolling stock, a wide gauge is the safest for high rates of speed.

The fifth and last reason assigned by your Chief Engineer, is really the *great* argument generally advanced by the advocates of the extreme narrow gauge theory. And yet I firmly believe it to be the weakest, and, if proper tests could be applied, the most easily exploded, of any of the arguments yet advanced in its favor.

But the great difficulty here, as in the other positions assumed in favor of this theory, is to apply the proper test. If we could have two parallel roads constructed, of equal lengths, grades, and curves, but of different gauges; and if we could have a given amount of passengers, and of the same kinds of freight, to transport over each, within a given time, and could be allowed to try experiments, as to the most economical mode of doing it, the problem could very soon be solved beyond a question.

Or, if any main trunk line had been constructed of the gauge recommended by your Chief Engineer, upon which a mixed freight and passenger traffic had been carried on during a series of years, the results of which could be compared with those of any other similar line, having the ordinary gauge, and doing the same amount and kind of business, we might then be able to procure some data upon which to base an argument.

But as we have neither of these examples before us, every one is allowed to form his own opinions from his own stand-point; and to advocate them in any manner, and for any purpose he pleases, apparently without any fear of successful contradiction.

It will be observed, however, that the entire argument is merely speculative, and that it is based upon pure assumptions, instead of upon facts as they are known to exist.

Your Chief Engineer assumes, as his fifth and last reason, that the percentage of dead weight to load, chargeable to the 3 ft. 6 in. gauge, is $\frac{47}{100}$; and that the same item chargeable to the 4 ft. 8½ in. gauge, is $\frac{75}{100}$, making a difference of $\frac{28}{100}$ in favor of the narrow gauge.

In another place he assumes, that the percentage of dead to live weight upon the 4 ft. 8½ in. gauge, is 100;

upon the 3 ft 6 in. gauge, 48; and upon the 3 ft. gauge, 56.

He also says: "In the above calculation I have used for the 4 ft. 8½ in. gauge, *the box car now in use.* For the 3 ft. 6 in. gauge, the *box car as presented in this report.* For the 3 ft. gauge, *the box car as constructed* at the Wilmington Car Works, *for the Denver and Rio Grande Railroad.*" I have italicised the portions of the above quotation to which I wish to call particular attention; and will only add the remark, that "*the box car now in use*" has been actually and thoroughly tested during many years, and has been found to answer the purpose admirably well; "*the box car as presented in this report,*" exists only in theory and upon paper; and "*the box car as constructed for the Denver and Rio Grande Railroad,*" if really constructed, has never been used sufficiently to test either its strength or durability.

The terminal stations of the New York Central, and the Erie railways, are within easy reach of your office. The difference between their respective gauges is greater than between the 3 ft. 6 in. and the 4 ft. 8½ in. gauges. The general character of their business is the same; and it is to be presumed that their rolling stock has been constructed, as to weight and dimensions, with due regard to the width of their respective gauges. I would therefore respectfully ask, whether it would not have been as well for your Chief Engineer to have obtained from these sources, some reliable data upon which to base his arguments, instead of basing them so entirely upon mere assumptions.

But as he has not done so, and does not give any reasons, either satisfactory or otherwise, for this apparent discrepancy between dead and live weight upon the respective gauges, I would respectfully ask him, why this percentage is necessarily greater upon the 4 ft. 8½ in. gauge, and less upon the 3 ft. gauge, than it is upon the 3 ft. 6 in. gauge? And will he, or any other of the many advocates of this extreme narrow gauge theory, undertake to demonstrate why a platform ten feet square, and capable of upholding a given maximum weight, should necessarily be of *more* than twice the weight and strength of one, ten feet long and five feet wide, and capable of sustaining just one half of the same maximum weight? And, again, if an ordinary four-wheel truck, duly proportioned to the size and weight of the respective loaded platforms, were to be placed underneath each platform, why it should necessarily require *more* than twice the power to move the larger, that it does to move the smaller platform?

These may be regarded as very trifling and unimportant questions. Yet, simple as they may appear, I am very much mistaken if they do not reach, and effectually undermine, the foundations of this narrow gauge theory, so far at least as it rests upon the great *dead weight* argument.

In the absence of any actual test, or other demonstration, I will venture the opinion that the larger platform, if constructed only of equal proportionate strength, will be found to be of *less* than twice the weight of the smaller one; and also, that *less* than twice the power will move it.

If there be even a slight possibility that my opinion is correct, then why not try, at least, this very simple and cheap experiment at once, instead of expending millions of dollars upon what must, at best, be regarded as a very questionable theory? The trial may be made at almost any time, upon any road, and with any gauge, by merely making a proper allowance for the unnecessary length and size of the axles underneath the smaller platform; and the experimental platforms may be of any relative width required to furnish the superficial area, or bearing surface claimed for the respective gauges.

This simple test would, in my opinion, decide the whole question, for the very simple reason, that these experimental platforms and trucks are the foundations which sustain all the superincumbent weight, and transmit it directly to the track underneath—whether this weight be in the form of additional length of platform, or of the superstructure of the car; or whether it be in the shape of paying freight and passengers.

I maintain, that the double truck flat, or platform car, is only an extension of these end platforms, properly connected together, and supported under the centre by a tension rod of iron ; and that the box car, and the passenger and saloon coaches, are only these very platforms and their extensions, sided up and covered over in a manner, and with a finish appropriate to their respective uses. And it is quite evident to my mind, that this superstructure above the platform, which encloses the space required to protect the load, need be no heavier upon the wider gauge, than the proportion justly due to the increased tonnage, or number of passengers which it is designed to enclose and protect. If doubts exist upon this point, however, the matter may be very easily settled by extending the scope of the proposed experiment with the platforms, so as to include fully completed box and passenger cars, of the length, width, and height proposed for the respective gauges.

But admitting, for the moment, that all the advantages claimed for the 3 ft. 6 in. gauge are, or appear to be, justly due to that gauge, I should still hold, that, with the exception of the slight percentage chargeable to the wider gauge for additional cost of construction, all these advantages can be realized with greater economy and safety, by using the same character of rolling stock upon the 4 ft. 8½ in. gauge. And that these advantages, if realized upon the wider gauge, would far overbalance the additional cost of construction.

It has been shown that the percentage chargeable to the additional cost of construction for the wider gauge, is very small, probably not exceeding 5 to 10 per cent. In order to adapt the rolling stock, which your Chief Engineer recommends, to the wider gauge, it would only require the lengthening of each axle 1 ft. 2½ inches. And the weight of this extra length of axle, and its cost, I claim to be the only items which, under this arrangement, can justly be charged, either as extra dead weight, or extra cost.

The advantages which I would claim for a road, thus constructed and equipped, over the one recommended by your Chief Engineer, would, in brief, be these :

1. If commercial advantages are to be gained by exchanging cars with connecting lines, you would be in a condition to secure them.

2. A train, like a wagon, may be hauled much easier with wheels of large than small diameter. This width of gauge allows of considerably larger wheels, under its *ordinary* rolling stock, than are admissible upon the narrow gauge; but with this proposed reduced height of cars upon the wider gauge, the wheels may be made so much larger, that a very material saving will be effected in power.

3. Having a greater base of track in proportion to the height and width of your cars, the irregularities in the track would be less apparent; and you could certainly make as fast time with greater safety, or faster time with equal safety than you could upon the narrower gauge.

4. The height and width of train being less than that in general use upon the wider gauge, the atmospheric resistance would also be proportionately less; and you could make faster time with the same amount of power than is made upon the ordinary 4 ft. 8½ in. railroads.

5. You would relieve the entire question, or at least the wider gauge portion of it, from the enormous load of extra *dead weight* which it has heretofore been compelled by its adversaries to carry, because under this arrangement it would evidently be reduced to merely the weight due to the extra length of axles.

6. If time and experience should happen to demonstrate that your Chief Engineer is wrong in his present convic-

tions upon this subject, you could correct the mistake hereafter at much less expense than you could if the grading, masonry, superstructure, rolling stock, &c., were all adapted to the narrow gauge.

If other reasons were wanting, I believe that those already given would fully justify the expenditure of the very small percentage of additional cost; and also the hauling of the very small additional amount of *dead weight* which would be fairly chargeable to this arrangement.

I have not deemed it important to notice particularly that portion of your Chief Engineer's report in which he compares the 3 ft. 6 in. with the 3 ft. gauge; neither have I paid any attention to his statements, figures, and illustrations, respecting the size, weight, and proportions of engines, cars, iron rails, &c., or to the centre of gravity, angle of stability, and laws of equilibrium, &c., &c., for the reason that I prefer that the advocates of all these extreme narrow gauge theories upon different gauges, should settle these details among themselves; and, also, for the further reason, that, if my conclusions are right, and theirs are wrong, in relation to the general principles which lie at the foundations of the entire narrow gauge theory, then these details are, comparatively speaking, of very little consequence.

I will venture the remark, however, in passing, that, if the comparisons which your Chief Engineer institutes between the 3 ft. 6 in. and the 3 ft. gauges are well founded, they would not only go very far towards weakening his argument against the 4 ft. 8½ in. gauge; but they would, if carried sufficiently far, be in great apparent danger of destroying the prestige claimed for the little Festiniog road in Wales.

Your Chief Engineer has omitted to urge one argument in favor of narrow gauge railroads, which is generally urged with great pertinacity by the advocates of that theory, although he fully endorses the principle. I refer to the advantage claimed for passing through curves. He says: "I concede the 3 ft. gauge has an advantage in turning acute curves ; but this is no argument; for, whatever might be the gauge of the track, I should locate the line of road as straight as possible, at the same time giving the question of economy due consideration."

Now, I respectfully submit, that, if the narrow gauge has the advantage claimed for it in this respect, it is a very strong argument in its favor, for the reason that the maximum load which can be hauled over any railroad with a given amount of power, is, with the present arrangement of machinery, governed as much by the increased resistance upon its curves, as by the increased relative resistance upon its grades. And, therefore, if this resistance upon curves is less upon the narrow than it is upon the wider gauge, it certainly is entitled to the full benefit of the argument.

But I believe this argument, like most of the others advanced in support of the narrow gauge theory, to be entirely fallacious.

There are two kinds of resistances which a curve imposes upon an engine and train while passing through it, that are not encountered upon a straight line. One of these is the impingement of the flange of the wheel upon the outer rail, while overcoming the direct, or tangential tendency of the train; and the other, is the sliding of the wheels upon one rail, a distance equal to the difference in the lengths of the two rails throughout the curve.

The resistance due to the impingement of the flange against the rail, is greatest upon curves of the smallest radii, and naturally diminishes as the radius increases, for the reason that the angle of impingement becomes less. Now, with a centre line of given radius, it is evident that the farther the outer rail of the curve is removed from this centre line, the greater will be the radius of the curve of the rail upon which this resistance occurs; and hence, the wider the gauge, the less will be the resistance.

The amount of extra power required, at any one time, to overcome the resistance caused by the sliding of the wheels which sustain one half the load, may be regarded as the same upon one gauge as the other; although the length of time during which, with a given rate of speed, this extra power must be exercised, is in proportion to the difference in length of the outer and inner rails of the curve; and this difference will, of course, be slightly in favor of the narrower gauge.

During the discussion of the gauge question before the Erie Company, the opinion of Mr. Robert Stephenson, as given before the Parliamentary Commission, was quoted by the advocates of the narrow gauge, to prove that the resistance was greatest upon curves of the wide gauge.

The following question was put to Mr. Stephenson by the Gauge Commissioners: "Is the lateral friction greater with one gauge than with the other?"

Answer, by Mr. R. Stephenson: "Any lateral friction that arises must be greater; for it arises from the angle of the wheel against the line, and it must be greater with the wide than with the narrow gauge."

This proposition was answered, and its error demonstrated so effectually, by Mr. S. S. Post, who was then acting as Engineer and Superintendent of the Eastern Division of the road, that I shall take the liberty of appending his argument for your information.

I have thus given you, at some length, my views in relation to the recommendations of General Buell, your Chief Engineer, as contained in his report; and I fear that these views, in some instances, may have been expressed more frankly, and with greater candor, than may prove to be entirely agreeable, either to yourself, or to him.

I was educated, as you are aware, in the Broad Gauge School, having spent the early portion of my professional life upon what is now the Erie Railway, and its branches and extensions, of which Company you were at that time an active and prominent Director. You can, therefore, make such allowances as you may think proper, for early prejudices, in what I have said or may say upon this subject. I am not conscious, however, of entertaining a feeling either of prejudice or of interest in the matter, my only desire being, if possible, to arrive at the truth.

You have done me the honor to ask for my written opinion: "as to whether a first-class railroad, of equal speed, comfort to passengers, and capacity for freight, with those possessed by the gauges now in general use, can be built upon a narrow gauge; and if so, what gauge would you recommend?"

In discussing a question of this importance it should be borne in mind, that the general adoption of the 4 ft. 8½ in. gauge, both in this country and in Europe, is not the result of accident, or the want of careful study and investigation.

When Mr. George Stephenson first conceived the great idea of adapting locomotive steam power to purposes of railroad transportation, it is true that the controlling idea of his practical mind was, not so much the establishment of the most useful and economical gauge, as it was the substitution of steam for horse power; but the roads, and the wagons upon and to which this new motive power was to be applied, had already been constructed of the 4 ft. 8½ in. gauge; and a long experience had shown them to be the best and most economical that could be devised for the use of horse power. Mr. Stephenson found no difficulty in adapting his machinery and power to that gauge; and he therefore adopted and advocated it during his long and eventful life. It therefore very soon became the ruling gauge of England; and, as the first locomotives that were used in the United States, were manufactured in England, it very naturally became the ruling gauge in this country.

At a subsequent period, the subject of gauges underwent a most searching investigation in England, by a Parliamentary Commission, before which Mr. Brunel and other distinguished engineers advocated a gauge of much greater width, while Mr. Stephenson and others adhered to the original gauge of 4 ft. 8½ in.; and this gauge was finally approved by the Commission.

At a still later day the question of gauges was thoroughly discussed by some of the best engineering talent in this country, before the New York and Erie Railroad Company; and that Company, being composed of some of the most practical and enlightened men in this city, after hearing the most exhaustive reports and arguments upon the subject, decided to adhere to the gauge of 6 ft., which had previously been adopted.

At another time the Legislatures of New Jersey and Ohio passed laws establishing the gauge of railroads, in their respective States, at 4 ft. 10 in., for the purpose, it is believed, of preventing an interchange of rolling stock between their own roads, and those of adjoining States. This restriction, however, if not repealed, has been in a great measure superseded by the very questionable, if not dangerous device, of the *broad-tread* or *compromise* wheel, which allows the same car to run over both the 4 ft. 8½ in. and the 4 ft. 10 in. gauges.

In many of the Southern States, and also in Canada, gauges of 5 and 5½ ft. have been adopted to a great extent, and used successfully during many years.

The original charter of the Union Pacific Railroad Company, provided that the President of the United States should decide upon the width of gauge for that road. Being then in the employ of the Government, at Washington, I was requested by the Secretary of the Interior to recommend a gauge to be adopted by the President. I accordingly recommended the 5 ft. gauge, which was approved. Congress, however, changed it afterwards, by special resolution, to 4 ft. 8½ in.; the argument urged in favor of the change being, that all eastward connecting railroads were of that gauge; and it would therefore be fatal to the enterprise, to make a break of gauge at the Missouri River.

In view of all these facts, it must be conceded that a great deal of thought, investigation, experience and legis-ation have already been bestowed upon the subject; but in no instance, so far as my knowledge extends, has the idea been seriously entertained or advocated, of reducing the gauge of main trunk lines of railway, below the limit of 4 ft. 8½ in., until the present agitation of the subject has given prominence to that idea.

And now, if this theory of extreme narrow gauges for all classes of railroads, shall prove to be well founded, it certainly becomes us to look about, and see whether the same radical error has not crept into our other methods of locomotion, transportation, and the various applications of natural and mechanical power. Whether our heavy draft horses, and clumsy carts and wagons, could not profitably be exchanged for a greater number of the more diminutive Shetland pony, with carriages to fit; or, perhaps, for something approaching still nearer to our single tracked wheelbarrow or velocipede. Whether our State canals should not have been made narrower instead of wider. Whether the streets in the lower portion of our city should not be diminished instead of enlarged in width. Whether our steamers and sailing vessels should not have retained their original dimensions, instead of growing to their present enormous proportions. Whether five hotels had not better be constructed, with accommodations for one hundred people each, instead of one single hotel with accommodations for five hundred people. And whether twenty stationary engines of five-horse power each, had not better be employed to do the work of one single engine of a hundred-horse power.

It is certainly important that these vital principles should be thoroughly examined; and if it shall be found that we have been living, during the past half century, under a radical mistake or illusion, it is high time that the mistake should be corrected, and the illusion dispelled.

It is quite evident, to my own mind, that this entire subject of railway gauges, has become too much confused and befogged by technical phrases, scientific terms, and glittering generalities. When stripped of these, it becomes simply a question of sound judgment, and good strong common sense.

Every intelligent farmer understands that a load of hay will tip over easier than a load of stone, simply because it is more *top-heavy;* but if you put your "centre of gravity," "angle of stability," and "laws of equilibrium" at him, he will become confused at once.

Every intelligent teamster, or carter, knows that he can haul a given quantity of tonnage a given distance, cheaper, if not quicker, by using a good, strong, double team with one suitable wagon; instead of by hauling, with the same team, two wagons of half the capacity each, one behind the other; or instead of dividing his team, and attaching one horse separately to each of the smaller wagons; simply because, in the case of the two smaller wagons, one behind the other, he has twice the number of axles to grease, and their friction to overcome; and at least one half of his load is too far behind his team to be handled easily; and in the case of two single horses hitched to two smaller wagons, he not only has twice the number of axles or journals, but he has an extra driver to pay; but if you should put the great *dead weight* and extra power arguments at him with all their force, ten to one he would not understand a word you might say.

And still, the great principles which underlie and should govern the construction and management of railroads, are simply these, or others equally practical in their application, and nothing more.

Applying these principles, as well as I am able, to the specific question of gauges now under consideration; and availing myself of a somewhat extended and varied experience, both in the construction and management of railroads, I am forced to the conclusion, that a first-class railroad cannot be constructed and operated with a gauge narrower than 4 ft. 8½ in., that will, if doing a large and miscellaneous business, combine all the elements specified in the interrogatory contained in your letter—to wit, "equal speed, comfort to passengers, and capacity for freight"—with as much facility and economy as the same elements can be combined upon the 4 ft. 8½ in., or even a broader gauge.

The subject, as presented to my mind, has naturally divided itself into the following general propositions:

1*st*. Comparative cost of construction.

2d. Comparative facility and economy in packing or loading.

3d. Comparative economy in hauling.

4th. Comparative advantages of a gauge common to connecting lines.

As to the first proposition, I am prepared to admit that the advantages are slightly in favor of the narrow gauge, but to nothing like the extent claimed by the advocates of the extreme narrow gauge theory.

As to the second proposition, I claim that the advantages are so greatly in favor of the wider gauge, that they very far outweigh the additional cost of construction.

I believe that the width of rolling stock, adapted to the 4 ft. 8½ in. gauge, can, if proper study and care are used in details, be constructed cheaper and of less weight, in proportion to its comfort and capacity, than rolling stock of the same relative width, strength, durability, comfort, and capacity can be constructed, and run with equal speed, economy, and safety upon a narrower gauge.

The comparisons that are constantly being made by the advocates of the extreme narrow gauge theory, between the weight and capacity of the rolling stock required for their favorite gauges, and that now in general use upon the wider gauge railways, both in this country and in Europe, is exceedingly unjust towards the broader gauge; for the reason that the extreme minimum of cost and weight has been studied and appropriated for their own gauges; and every inch of space is assumed as being occupied during the entire trip with *live* or paying weight; while, for the wider gauges, they adopt for the comparison, a miscellaneous outfit, made up without strict regard to these elements of cost and weight, and used promiscuously for way and through business—sometimes full, sometimes partially loaded, and sometimes entirely empty, according to the nature of the traffic, or the circumstances which control the business of the road.

They seem to imagine that all these contingencies would be avoided upon the narrower gauge, even if it were doing the same kind of business.

But let the test, which I have suggested in another place, be fairly applied to this question, and I am perfectly content to abide the result.

I am prepared to admit, that a great deal of unnecessary and non-paying weight, as well as useless and injurious friction, are constantly being hauled over our railroads. And I trust that the ventilation which this subject is now undergoing, will have a tendency to correct this particular evil, even if nothing better shall result from it. I might illustrate this proposition by referring to the enormous and unnecessary weight of some of our passenger, drawing-room, and sleeping cars, in proportion to the number of passengers which they accommodate. Many of these are nearly as heavy as the engine that hauls them; and they are often obliged to be coupled as near the engine as possible, in order to be moved at all.

I cannot admit, however, that this evil is in any degree chargeable to the width of track. It results entirely from the excessively *broad gauge* of the managers of some of our railways; and of the caterers to the public taste, who are allowed to come between the public, and the stockholders who construct the road, and furnish the power to haul these cars; and this evil would be as likely to occur upon one gauge as another.

As to the third proposition, with reference to the comparative cost and application of locomotive power upon railways of different gauges, I will respectfully refer you, for actual results upon the 6 ft. gauge, to the appended extract from General McCallum's Report, upon the New York and Erie Railroad; and for actual results upon the 4 ft. 8½ in. gauge, to a communication which has been kindly furnished me by Mr. H. Stanley Goodwin, Assistant General Superintendent of the Lehigh Valley Railroad, which will also be found in the Appendix. But, for the narrow gauges, I can, unfortunately, refer you only to *theoretical* and *assumed* results; and I do not regard these as being sufficiently reliable, either to warrant a comparison with known results upon the broader gauges, or to justify any conclusions that might result from such a comparison.

From General McCallum's Report it appears:

1. That an engine of 66,050 lbs. total weight, and having 40,050 lbs. weight upon the driving wheels, hauled a train consisting of 100 loaded cars, weighing 3,423,150 lbs., over a mile of road, on an ascent of 6.14 ft., and a curve of 5,730 ft. radius, in 11½ minutes.

2. That the same engine hauled a train of 22 loaded cars, weighing 753,082 lbs., over a mile of road, on an ascent of 60½ ft., and a curve of 1,146 ft. radius, in 6½ minutes.

3. That the same engine hauled a train of 25 loaded cars, weighing 870,250 lbs., over one mile of road, on an

ascent of 52 ft., and a curve of 1,146 ft. radius, in 9 minutes.

4. That the same engine hauled a train of 23 loaded cars, weighing 800,330 lbs., over one mile of road, on an ascent of 60 ft., and a curve of 1,637 ft. radius, in 5 minutes.

5. That the same engine hauled a train of 24 loaded cars, weighing 821,544 lbs., over one mile of road on an ascent of 60 ft., without curvature, in 5½ minutes.

6. That the same engine took the same train up the next mile, on a grade of 58 ft., and through a curve of 3½° per 100 ft., in 8½ minutes.

It appears from Mr. Goodwin's letter:

1. That the engines in ordinary use upon the Lehigh Valley road, are of two kinds: 1st, the ordinary 10 wheel engine, weighing from 76,400 lbs. to 78,000 lbs. with fire and steam, of which from 61,600 to 63,000 lbs. weight is on the 6 drivers, and the remainder upon the leading truck; 2d, the other kind of engines called "Consolidation," weigh 86,000 lbs. with fire and steam, of which 76,000 is on 8 drivers of 4 ft. diameter.

2. That the average weight of freight cars, in general use upon that road, is $3\frac{4}{10}$ tons each, and that the average useful load which they carry is $5\frac{4}{10}$ tons each, making $8\frac{8}{10}$ tons of car and load.*

3. That the heaviest traffic upon that road is upon 46 miles, where the grade is either level, or descending at the

* Please note here the discrepancy between *facts* and *assumptions*.

rate of 20 ft. per mile, and that upon this portion there are many curves of 955 ft. radius.

4. That upon this portion, an engine can haul down, with the same ease, the number of loaded cars that the same engine will haul up empty.

5. That this number averages in good weather, 150 cars, hauled with the 10 wheel engines, and in some cases has reached 200.

6. That the "Consolidation" engines have hauled 250 cars over the same road, "and could probably exceed 300 before reaching the engines' capacity."

7. That upon 12 miles of another portion of the road there is a grade of 96 ft. per mile, with curves of 955 ft. radius. Up this grade the 10 wheel engines haul 22 loaded cars, weighing 194 tons; and the "Consolidation" engines haul 33 loaded cars, weighing 290 tons.

8. That upon an ascending grade of 146 ft. per mile for 2 miles in length, the 10 wheel engines haul 37 empty cars, weighing 122 tons, and the "Consolidation" engines haul 55 empty cars, weighing 182 tons.

The foregoing synopsis of general results contains, perhaps, all the information upon this point that is required for the purpose of instituting a comparison between the relative cost of power upon the 6 ft. and the 4 ft. 8½ in. gauges respectively; and also to deduce a result which would logically follow, upon a comparison between the 4 ft. 8½ in. gauge, and the narrower gauges.

But I will leave the labor of such a comparison to be performed by the advocates of the extreme narrow gauge theory, and close what I have to say upon this branch of the subject with the single remark, that until this is satisfactorily done; or until such other practical tests are applied to the narrow gauges as will demonstrate, beyond a question, their superiority in this, as well as in the other respects referred to, they should not expect, with so much apparent confidence, that their favorite system will so soon supersede the one which has been in use so long and so successfully.

As to the fourth proposition, with reference to continuous gauges, it being more of a commercial than an engineering question, I would not speak with so much confidence, although I should, at the present time, and under all the circumstances, probably recommend the 4 ft. 8½ in. gauge, as the standard gauge of the country. I have never been an advocate, however, of continuous gauges upon main trunk connecting lines of railway, merely for the purpose of avoiding the necessity of changing cars, and breaking bulk.

I believe that the great damage and inconvenience growing out of an interchange of cars upon thousands of miles of connecting, and in many instances hostile or competing lines, very often overbalance any good, or real saving to the stockholders, that may result from it; although, like all other rules, it probably has its exceptions. If the truth could be ascertained, I have no doubt that the present mania for harmonizing gauges, and consolidating lines, is more the result of a desire, on the part of ambitious managers, to overreach competing lines, by the establishment of agencies and other influences very far in advance of them, than any saving in the actual cost of transportation, that, as a general rule, can be shown to result from it.

Inasmuch, however, as the opinion of a practical railway manager of high reputation, and of a much larger experience in such matters than my own, should have much greater weight than any that I would venture to advance, I will append an extract from a very able and comprehensive report made in 1856, to the New York and Erie Railroad Company, by General D. C. McCallum, then General Superintendent of that road, and afterwards, during the late rebellion, the General Manager of all the military railroads in the United States; and as the same report contains, in the same connection, important facts and arguments bearing upon the subject now under consideration, relative to the application of power; the comparative economy of transportation upon different gauges, and the relation which the width of gauge should bear to the amount of business to be done. I will also take the liberty of embodying these in the extract, for your information.

Having expressed an opinion so decidedly against *all* gauges of a width less than 4 ft. 8½ inches, it will probably be regarded as supererogatory for me to furnish an answer to the concluding part of your question, to wit, "and if so, what gauge would you recommend?"

I trust, however, that I may be permitted to state the reasons which influenced me in recommending the gauge of the Union Pacific Railroad and its branches, to be established at five feet.

I believed then, and now believe, that experience has demonstrated that the width of rolling stock in general use upon the 4 ft. 8½ in. gauge, is none too wide to afford the necessary and proper comfort to passengers, and stowage capacity for the average ruling classes of freight that are generally offered for transportation on the main trunk lines of railroad in this country. I also believe that the gauge of 4 ft. 8½ in. has been found somewhat too narrow to afford the requisite base for this width of rolling stock, to insure a full measure of economy and safety, particularly if run at high rates of speed over our somewhat imperfect and uneven railroad tracks.

This disproportion between the widths of gauge and rolling stock, has undoubtedly grown out of an effort on the part of the 4 ft. 8½ in. gauge managers, to reach, as nearly as possible, the width of freight and passenger cars used upon the wider gauges of 5½ and 6 feet, and thus afford (approximately at least) the same "comfort to passengers and capacity for freight" that are claimed for these wider gauges. In doing this, I think they have slightly overreached the verge of safety, if not of strict economy; and, therefore, a gauge of five feet placed under the same rolling stock, would, to some extent, correct this error. Inasmuch, therefore, as I then believed that the great pioneer line, extending from the Missouri River to the Pacific Ocean, would, for many years at least, have no competitor; and that it could, therefore, very well afford to run and control its own rolling stock; and that other Pacific lines, when built, would, in all probability, follow its example, I had no hesitation in recommending the 5 ft. gauge.

The foregoing may be regarded as only a demonstration, based upon general principles, of the fallacy of the extreme narrow gauge theory, as applied to all main trunk lines of railway in this country.

When these principles are applied particularly to the proposed Texas Pacific Railroad, I think they will be found to possess peculiar force.

Your road, when completed, will necessarily come into direct competition, for the great trans-continental traffic, with the Central, Union, and Kansas Pacific Railroads, which are already constructed; and which, with their numerous connections eastward of the Missouri River, form continuous lines from the Pacific Coast, at San Francisco, to the great commercial ports upon the Atlantic seaboard.

The Northern Pacific Railway is now under construction, from Puget Sound, upon the Pacific, to our great inland Lakes, and thence by numerous connecting lines to the Atlantic coast. And it will therefore very soon become another formidable competitor for this immense traffic.

The Canada Pacific Railroad will also, in all probability, very soon be constructed, and form a continuous line from Puget Sound, to the head of deep ocean steam navigation upon the St. Lawrence River at Quebec; thus forming another competitor for the traffic across the continent.

These great competing lines will all have an unbroken gauge of 4 ft. 8½ in. throughout their entire length, from Ocean to Ocean.

I would, therefore, regard the commercial argument in favor of an unbroken gauge, of at least equal width, for the Texas Pacific Railroad, extending as it will from San Diego on the Pacific, to the Mississippi River, and thence with its connections, eastward to the Atlantic Ocean, as being entirely unanswerable—not upon the ground that it can be defended upon strictly scientific and abstract principles: but for the more practical reason, that this theory of *funding* gauges, as well as stocks, has become the popular and settled policy of the country, with reference to our great competing lines of railway; and as such, is looked upon with favor, not only by those who furnish capital to construct these lines, but by those who provide business for them after construction.

If, therefore, the construction of your road should be undertaken upon an inferior gauge; and one that would necessarily form a break with all its railroad connections east of the Mississippi River, I should very much fear that capitalists would hesitate to furnish the means required for its construction; and that, if constructed, the travelling public, as well as the heavy freighting interests of the country, would discriminate largely against it.

Thanking you for the confidence which you have manifested in my opinion, upon a subject of this magnitude; and hoping that the views herein expressed may aid you to some extent, in arriving at a correct conclusion upon a matter so important to the ultimate success of the great enterprise which you have in hand,

I have the honor to remain,

Yours, very respectfully,

SILAS SEYMOUR.

To MARSHALL O. ROBERTS, Esq.,

President of the Texas Pacific Railroad Company,

New York.

APPENDIX.

A Paper contributed by Mr. S. S. Post, *Civil Engineer, in relation to the comparative resistance upon railway curves of different gauges :*

On a railroad having two tracks, it is presumed that the centre line between the tracks is the centre of location: and that the centre line will remain the same, whether a wide or a narrow gauge of track be adopted.

It is supposed, also, that the width necessary between tracks will in either case be the same ; then one line of rails in each track will be common to both gauges: and, upon a curve, one will be the *inner rail* of one track, and the other the *outer rail* of the other track.

The tendency of a locomotive, upon entering a curve, is to pursue a direct, or tangential course: and this tendency is overcome by the resistance of the *outer rail* acting against the flange of the leading wheel.

This impinging upon the rail does not take place on a straight road, where the line of motion is parallel with the lines of the rails. In passing through a curve, therefore, it must be caused by the line of motion forming an angle with the line of the outer rail, the resistance of which, to the flange of the wheel, constantly changes the direction of the line of motion.

It is evident that this resistance will be more or less, as the angle is greater or smaller; and that the angle is greater as the radius of curvature of the outer rail is less. It is also evident that the radius of the *outer rail* of the *inner track* will be the same, let the width of that track be what it may; and that any different resistance of the curves, in consequence of the difference of gauges, can take place only at the *outer* rails of the outer tracks.

Let it be supposed that the radius of the centre line of a railway curve is 1,000 feet, and that the tracks are 6 feet apart; and let it be required to determine the resistance of the outer rail to the flange of the leading wheel of a locomotive engine, upon a track 6 feet wide, and also upon a track 4 ft. $8\frac{1}{2}$ inches wide.

Then the radius of the curve of the outer rail of the 6 ft. track will be 1,009 ft., and of the 4 ft. $8\frac{1}{2}$ inch track 1,007 ft. $8\frac{1}{2}$ inches, or $1,007\frac{7}{10}$ ft. very nearly. The gauge of the wheels, or distance between the flanges, where they touch the rails, is usually about $\frac{3}{4}$ of an inch, say $\frac{6}{100}$ of a foot, less than the gauge of the rails, and the average distance at which the flanges run from either rail, when upon a straight line, will not differ much from $\frac{3}{100}$ of a foot.

Let, therefore, the flange of the wheel enter the curve at the distance of $\frac{3}{100}$ of a foot from the rail, and continue in the same direction, until it touches the curve, then this point of contact will be at the extremity of an arc, of which .03 will be the *versed sine*; and the distance moved by the wheel, after entering the curve, will be the *sine* of the same arc.

$$\left(\overline{(1009 \times 2} - .03) \times .03\right)^{\frac{1}{2}} = 7\tfrac{7807}{10000} \text{ feet}$$

will be the distance moved on the wide gauge: and

$$\left(\overline{(1007.7 \times 2} - .03) .03\right)^{\frac{1}{2}} = 7\tfrac{7757}{10000} \text{ feet}$$

the distance moved on the narrow gauge, after entering the curve, before the impinging action will commence.

Now, $\frac{7.7807}{1009} = .0077113$ is the *natural sine* of the angle of resistance upon the outer rail of the *wider* track; and $\frac{7.7757}{1007.7} = .0077156$ is the natural sine of the angle of resistance upon the outer rail of the *narrow* track, at the points where the flanges begin to impinge.

The first angle is therefore $0^\circ\ 26'\ 30\frac{160}{273}''$: and the other is $0^\circ\ 26'\ 31\frac{129}{273}''$; making the angle of resistance $\frac{349}{573}$ of a second less, upon the wide than upon the narrow track.

Assuming the adhesion of the wheels to the iron rails to be equal to $\frac{1}{5}$ of the whole weight of and upon the truck of an engine or car, then the force of $3.\frac{08452}{100000}$ lbs. per ton (2,000lbs.), will be required to overcome the resistance on the wide track; and $3.\frac{08624}{100000}$ lbs. per ton on the narrow track; making a difference of $\frac{172}{100000}$ lbs. per ton, which, although scarcely appreciable, is in favor of the wide gauge.

The above calculation does not, of course, take into account the *centrifugal force* of the engine or train; but the power required to resist or overcome this force is inversely as the radius of curvature, the weight and velocity being the same. For $F = \frac{w}{g} \times \frac{v}{R}$ represents the centrifugal force, when w is put for the weight, g the gravity, v the velocity, R the radius, and F the force.

It will be seen at once, on inspection of the formula, that F is diminished as R is increased. Admitting, however, that the centrifugal force is as much in the case of the *wide* as the *narrow* gauge, still this force is resisted and overcome by the same means; and the power required is *in favor of the wide track*, in precisely the same proportion, as for overcoming the other resistance, as above stated.

Hence it appears that Mr. Stephenson's answer to Question 241 is entirely erroneous.

Extract from a report made by General D. C. McCallum, *General Superintendent, to the New York and Erie Railroad Company, dated March 25, 1856*:—

EXPERIMENTS FOR DETERMINING EFFECT OF GRADES AND CURVATURE.

Experiments were made in September last, with the view of determining the relative power required upon the several Divisions of the road for the transportation of heavy freight, by ascertaining the maximum load any given engine can haul over those portions of each Division which limit the load.

For this purpose, a single locomotive engine was run the entire distance from Dunkirk to Piermont, with trains varying to suit the ruling grades of the respective Divisions. As these experiments were not intended to set at rest questions of a purely scientific character, the accuracy necessary to that end was not observed. It is believed, however, that they have been made with sufficient care to determine the practical objects more immediately in view; and show the capacity of the road and its machinery to be adequate to the movement of an immense tonnage, *and at a less cost per ton, for a large traffic*, than can be attained on any road of less gauge, and of equal grades and curvature.

The engine selected for this purpose was of the following proportions :—Total weight, 66,050 lbs. ; Weight on driving wheels, 40,050 lbs. ; Cylinders, 17 in. diameter ; Length of stroke, 24 in. ; Driving wheels, 5 ft. diameter ; Maximum pressure of steam on cylinders without slipping the wheels, 140 lbs. ; or, deducting the atmospheric pressure, $125\frac{3}{10}$ lbs. effective pressure per square inch.

The traction of the engine, that is its power applied at the circumference of the wheels and by which it is impelled, neglecting its friction, may be stated thus:

$$\frac{125\frac{3}{10} \times 17 \times 17 \times 24}{60} = 14{,}485 \text{ lbs.}$$

This is the total resistance, consisting, principally, of the friction of the engine and tender, of the cars, the gravity of the train on ascending grades, and the resistance of curves, which this engine, under an effective pressure of $125\frac{3}{10}$ lbs. per square inch upon its pistons, can overcome.

The engine and tender were moved with slightly accelerated motion, on a level, under an effective pressure of 3 lbs. Their friction, therefore, without any load attached, is:

$$\frac{3 \times 17 \times 17 \times 24}{60} = 347 \text{ lbs.}$$

It has been customary to estimate the friction of cars, with wheels of 30 in. and journals of 3 in. diameter, at about 7 lbs. per ton, or, 8 lbs. per ton for wheels 33 in. and journals $3\frac{7}{8}$ in. diameter—the dimensions of those in use on this road; but the experiments made, show conclusively that the friction of the loaded cars did not exceed $4\frac{1}{2}$ to 5 lbs. per ton.

It has also been usual to estimate the additional friction of the engine, in consequence of its load, at one pound per ton of its load on a level. This item will of course be reduced as the friction of the cars is reduced.

After a careful examination and comparison of the loads moved upon the ruling grades and curves of various sections of the road, it is assumed that the friction of the cars is $4\frac{1}{2}$ lbs. per ton of 2,000 lbs.; the resistance of curves $\frac{1}{2}$ lb. per ton per degree of curvature per 100 ft.; and the additional friction of the engine $\frac{1}{2}$ lb. per ton of load on a level and straight line, or its equivalent.

The weight of the engine on its drivers being 40,050 lbs., and the traction 14,485 lbs., the adhesion was, therefore, $\frac{14485}{40050} = \frac{36}{100}$, or not less than 36 per cent. of the insistant weight. This has heretofore been variously estimated at from $12\frac{1}{2}$ to 25 per cent.

The tender, with its complement of wood and water, weighed 40,240 lbs.

A train consisting of 100 loaded cars, weighing 3,423,-150 lbs., making the total weight of engine, tender and cars, 3,529,440 lbs., or 1,765 tons, very nearly, was taken over a mile of road, on an ascent of 6.14 ft., and a curve of 1° or 5,730 ft. radius, in $11\frac{1}{2}$ minutes. The preceding mile being on an uniform grade of 6 ft., ascending also, no advantage could have been taken of momentum previously acquired by the train.

The resistances overcome in this case are estimated as follows:

Friction of engine and tender, - - - - - -	347 lbs.
" cars $1{,}711\frac{575}{1000}$ tons at $4\frac{1}{2}$ lbs., - -	7,702 "
Gravity of engine and train $\frac{3{,}529{,}440 \times 6.14}{5{,}280}$ -	4,104 "
Resistance of curve $1{,}765 \times \frac{1}{2}$ lb., - - - - -	882 "
Additional friction, $\frac{1}{2}\left(\frac{4{,}104 + 882}{4\frac{1}{2}} + 1{,}711\frac{575}{1000}\right)$	1,410 "
Total resistances, - - - - - - - - - -	14,445 lbs.

or 40 lbs. less than the estimated traction.

A train of 22 cars, weighing 753,082 lbs. or $376\frac{541}{1000}$ tons, and with engine and tender weighing 859,372 lbs., or $429\frac{686}{1000}$ tons, was taken up a mile of $60\frac{1}{2}$ feet ascending grade, through a curve of 5° or 1,146 feet radius, in $6\frac{1}{2}$ minutes.

Friction of engine and tender, - - - - - -	347 lbs.
" cars $376\frac{1}{2}$ tons at $4\frac{1}{2}$ lbs. - - - -	1,694 "
Gravity of engine and train, $\frac{859{,}372 \times 60.5}{5{,}280}$ -	9,847 "
Resistance of curve $429\frac{686}{1000} \times 2\frac{1}{2}$, - - - - -	1,074 "
Additional friction, $\frac{1}{2}\left(\frac{9.847 + 1{,}074}{4\frac{1}{2}} + 376\frac{1}{2}\right)$	1,401 "
Total resistance, - - - - - - - - - -	14,363 lbs.

or 122 lbs. less than the maximum traction, or power of the engine under an effective steam pressure of $125\frac{3}{10}$lbs. per square inch.

On a mile of 52 feet ascending grade and a curve of 5° per 100 feet, or 1,146 feet radius, a train of 25 loaded cars, weighing 870,250 lbs. or $435\frac{1}{8}$ tons, and with engine and tender 976,540 lbs. or $488\frac{77}{100}$ tons, was taken up in 9 minutes.

Friction of engine and tender, - - - - - -	347 lbs.
" cars $435\frac{1}{8}$ at $4\frac{1}{2}$ lbs., - - - - - -	1,958 "
Gravity of engine and train, $\frac{976,540 \times 52}{5,280}$ - -	9,618 "
Resistance of curve $488\frac{77}{100} \times 2\frac{1}{2}$, - - - - -	1,220 "
Additional friction, $\frac{1}{2}\left(\frac{9,618 + 1,220}{4\frac{1}{2}} + 435\frac{1}{8}\right)$	1,422 "
Total, - - - - - - - - - - - - - -	14,565 lbs.

being an over estimate of resistances, or an under estimate of traction of 80 lbs.

On a mile of 60 feet ascending grade, through 2,900 feet of curve $3\frac{1}{2}$° or 1,637 feet radius, a train of 23 loaded cars, weighing 800,330 lbs. or $400\frac{165}{1000}$ tons, and, including engine and tender, a total weight of 906,620 lbs. or $453\frac{31}{100}$ tons, was taken up in 5 minutes.

Friction of engine and tender, - - - - - -	347 lbs.
" cars, $400\frac{1}{6}$ tons at $4\frac{1}{2}$ lbs., - - -	1,800 "
Gravity of engine and train, $\frac{906,620 \times 60}{5,280}$ - -	10,302 "
Resistance of curve, $453\frac{31}{100} \times 1\frac{3}{4}$ - - - - -	793 "
Additional friction, $\frac{1}{2}\left(\frac{10,302 + 793}{4\frac{1}{2}} + 400,\right)$ -	1,433 "
Total, - - - - - - - - - - - - - -	14,675 lbs.

or 190 lbs. over estimate of resistance.

A train of 24 cars, weighing 821,544 lbs. or $410\frac{772}{1000}$ tons, total weight, including engine, 927,834 lbs. or $463\frac{917}{1000}$ tons, was taken up a mile of 60 feet grade, without curvature, in $5\frac{1}{2}$ minutes.

Friction of engine and tender,	347 lbs.
" cars, $410\frac{8}{10} \times 4\frac{1}{2}$	1,848 "
Gravity, $\frac{927,834 \times 60}{5,280}$	10,543 "
Additional friction, $\frac{1}{2}\left(\frac{10,543}{4\frac{1}{2}} + 410\frac{8}{10}\right)$	1,377 "
Total,	14,675 lbs.

Resistance less than traction 370 lbs.

The same train was taken the next mile on a grade of 58 feet, through a curve of $3\frac{1}{2}°$ per 100 feet, for 1,500 feet, in $8\frac{1}{2}$ minutes.

Friction of engine and tender,	347 lbs.
" cars, $410\frac{8}{10} \times 4\frac{1}{2}$,	1,848 "
Gravity, $\frac{927,834 \times 58}{5,280}$	10,192 "
Resistance of curve, $463\frac{9}{10} \times 1\frac{3}{4}$,	812 "
Additional friction, $\frac{1}{2}\left(\frac{10,192 + 812}{4\frac{1}{2}} + 410\frac{8}{10}\right)$	1,428 "
Total,	14,627 lbs.

or over estimates of resistances of 142 lbs.

The average of these six experiments shows an estimated resistance of 14,465 lbs., or 20 lbs. less than the traction or computed maximum power of the engine with the steam gauge indicating 140 lbs. pressure.

The ultimate power of a well proportioned engine, may be most easily and correctly determined from the weight on its driving wheels. From the experiments made, we are able to deduce practical rules for ascertaining the gross weight of cars and useful load which an engine should take behind its tender.

COMPARISON OF GAUGES.

Inasmuch as the results of these experiments are somewhat extraordinary in their character, it may be claimed that the resistances assumed are too small; but then it must also be admitted that the adhesion was greater than has been stated, and it must be conceded that practically, an additional adhesion of not less than ten to fifteen per cent. has been attained on this road by the skill of engineers in applying the steam and managing their engines with heavy loads. On the other hand, if it be denied that the adhesion was as great as stated, then it must follow that the friction of the cars and other resistances have been over estimated. Whilst these experiments furnish valuable data for the purposes for which they were more particularly made, they have already shown the great advantages which are derived from the six feet gauge in the transaction *of a heavy freight traffic*, particularly upon roads having unfavorable grades and curvature.

Permit me to state here, that it is not my purpose at present to provoke a discussion as to the relative merits of the broad and narrow gauge, as that question, so far as this road is concerned, has been fully settled. I may be excused, however, for alluding to the subject in connection with these experiments, as a large number of our prominent Stockholders, and others whose opinions are entitled to consideration, still believe that the adoption of the wide gauge has proved seriously detrimental to the interests of the Company. It is gratifying therefore to be able to dispel these doubts, by pointing to the experiments referred to as proof of the fact, that what was originally claimed for the 6 ft. gauge, has been fully confirmed by practical experience.

Soon after the completion of the road to Otisville, the question of location having been disposed of, the Company were in a condition to place a large portion, west of that point, under contract; but about that time grave doubts were entertained and suggested, as to whether the broad gauge previously adopted, or the narrow gauge in common use in other parts of the State, was the best adapted to the business of the road. Before determining this question, the Board of Directors deemed it expedient to examine the arguments of the advocates of each; and with this view passed a resolution calling upon their Chief Engineer, Consulting Engineer, and Superintendent, for reports, giving their opinions in regard to the relative merits of the 6 ft., and 4 ft. 8½ in. gauges. A diversity of opinion on this subject existing amongst these gentlemen, a lively discussion was provoked, and each, in his zeal to fortify himself in the position assumed, strengthened it by appending to his report the arguments and opinions of individuals of the most eminent practical and scientific attainments in this country and in England. The evidence given before the Commissioners appointed by the British Parliament to investigate the subject of gauges, was freely used in this discussion, and such a mass of information elicited as to place the Board in possession of all the prominent arguments for and against both.

After mature deliberation, and a full and impartial investigation of the subject, the Board of Directors passed a resolution adopting the 6 ft. gauge: and, after practically testing its merits, it cannot fail to be gratifying to its advocates to find their judgment confirmed by a demonstration of its decided superiority, for the business of this road, over the narrow gauge that was recommended in its stead.

It may not be improper in this place to allude to arguments that were prominently used in opposition to the introduction of the broad gauge, the fallacy of which I think the experience of this road has fully proved.

Whilst admitting that a gauge of 6 ft. would enable the introduction of engines of much greater capacity than could be obtained by the adoption of a gauge of 4 ft. 8½ in., it was claimed that the latter would admit the *use* of engines of a capacity sufficient to haul as many cars as were considered profitable to connect in a single train; as much greater strength would be required in the drawheads and couplings in order to make the additional power available. It has been found by experience that there is no difficulty in giving all the strength required, and that a load equal to the most powerful engine upon the road, rarely produces the result apprehended.

It was also said that *uniformity of gauges* was necessary to the economical transportation of freight; and that a departure from the uniformity hitherto preserved would involve additional expenditure in loading and unloading freight, between all connecting roads having different gauges, as they would, from this cause, be precluded from interchanging cars ; the disparity limiting their use to the particular road to which each was adapted.

Plausible as this argument may at first sight appear, it is, nevertheless, in point of fact, not true as to the *economical* effects claimed; as the cost of transferring freight from the cars of one road to those of another with which it connects, is less than that of hauling the "empty returned cars" back—rendered necessary in cases where the freight is sent east—the preponderance of trade being largely in that direction. It may be said, the "dead weight" hauled would be the same whether the load was conveyed in cars belonging to this or some other road ; but such is not the case, as the cars belonging to this road may be used in transporting local freights on their return, between intermediate stations, so as to be partially loaded at least ; whilst in the other case, the cars must be promptly returned to their owners for use.

This system of interchange of cars, so far as short roads are concerned, is undoubtedly beneficial ; but if applied in connection with long roads, the benefits will be found to be derived at the expense of the latter, as in the settlements between the two, the payments for "mileage" for the use of cars will invariably be in favor of the short lines. The long roads by this system are frequently compelled to pay the hire of rolling stock of inferior construction (their own, perhaps, in the mean time standing idle), and also to expend large sums to keep such cars in repairs ; as they are not unfrequently sent from one road to another in such a dilapidated condition as to involve the necessity of switching them out of the train before reaching their destination, making it often necessary to reship goods at points where it is not only inconvenient but expensive to do so. This has been the experience of this road, and our accounts show that it has cost this Company nearly double the amount per mile run, for the repairs of cars belonging to other lines, that has been expended on their own. These objections have been found so serious in their character, that it has been deemed necessary to almost entirely discontinue the system of interchange, although the lateral roads connecting with this were constructed, of the same width of gauge, with that particular object in view.

Whatever advantages may be claimed for the system, in its application to short roads forming the same line, or to lateral roads connecting with main trunks, I have no doubt it can be clearly shown that companies owning the latter, have nothing to gain, but much to lose, by such an arrangement; and I confidently believe that the experience of railroad managers generally, will bear me out in the remark, that a road five hundred miles in length, with a gauge that does not correspond with that of any independent line with which it connects, enjoys in this particular, an enviable position.

An accurate account of the cost of loading and unloading has been kept at the Dunkirk station, from which it appears the expense is about seven cents a ton, certainly a much less sum than the cost of hauling the extra dead weight, repairs of cars, and wear and tear of machinery, involved by the interchange of cars.

I will also allude to another argument used in opposition to the introduction of the broad gauge, viz., the supposed greater resistance offered by its curvature.

If we analyze the resistance opposed to the passage of a train through a curve, two species of friction, besides those existing on a straight track, will be found. One is caused by the necessity for the wheels on one rail to slide through a portion or the whole of a distance equal to the difference in the lengths of the inner and the outer rails. The other is caused by the impinging of the flanges of the wheels against the outer rails, in overcoming the tangential tendency of the trains.

The difference in the lengths of the inner and the outer rails, for a degree of curvature, is, for a track of 6 ft. gauge, $\frac{1048}{100000}$ of a foot, and for a track of 4 ft. 8$\frac{1}{2}$ in. gauge, $\frac{822}{100000}$ of a foot, making a difference between the two guages of $\frac{226}{100000}$ of a foot, or less than $\frac{5}{16}$ of an inch in one hundred feet, through which additional distance *one half* the weight of the train is supposed to slide.

Now, if we suppose locomotives, or cars, or trains of equal weight, to traverse curves of equal radii, it is quite immaterial as to what width the gauge of the track may be; for the same weights will in any case be imposed upon either rail, whether far apart or near to each other; and each ton of weight will slide as easily through a distance of one hundred feet in one case as in another.

The power that can slide or overcome the friction of one ton, or any number of tons, on the surface of the rails, for one hundred feet, if continued to be exerted, will continue to overcome the same degree of friction for $\frac{5}{16}$ of an inch not only, but for an indefinite distance; *therefore the* *power of a locomotive is not diminished*, in this particular, *by the width of the track.*

In locating a railroad, the engineer traces a line called the "centre line of location." (See illustration.) This line is, also, usually made either the "centre line" of a single track, or the centre line between two tracks. The "centre line" would not be varied by the adoption of either a wide or a narrow track.

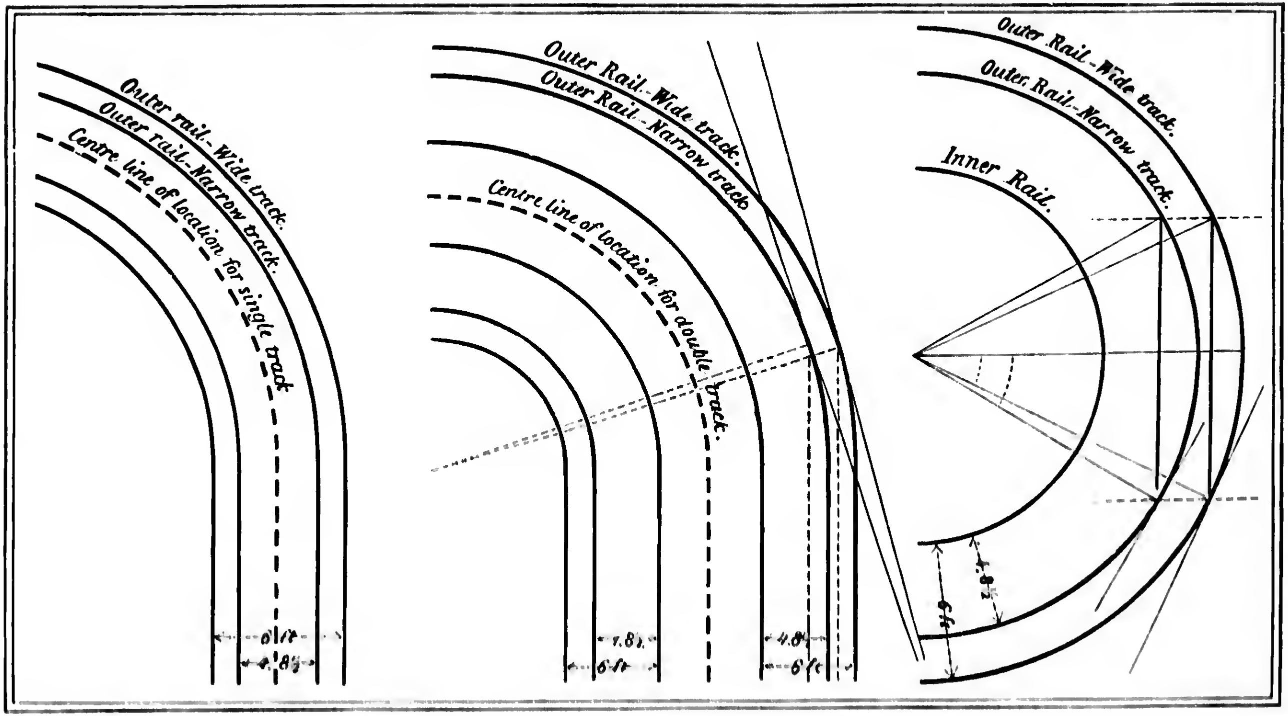
It is obvious that, upon a curved track, with a centre line of fixed radius, the wider the gauge the greater will be the radius of curvature of the outside rail, and consequently, the nearer to a straight line will a given length of that rail approach.

A chord line of given length will coincide more nearly to an arc of the larger curve, and make a smaller angle with it, than with a curve of less radius. The wheels of a truck occupy the position of this chord, with reference to the outside rail.

The angle, therefore, at which the flange of a wheel, on entering and passing through a curve, will impinge upon the outer rail, being less on a wide than on a narrow track, it follows that the *momentary resistance*, from this cause, *is least on the wide track*, though it may be slightly increased in duration.

In concluding my remarks upon this subject, permit me here to state, that although the gauge of this road is all that could be desired for the extent and character of its business, it does not follow that its *general adoption* would be either wise or economical, as it is with railroads as

Diagrams Illustrating Remarks on the Effect of Curvature on Different Gauges.



with all other modes of transportation, the magnitude of the arrangements should be in proportion to the amount and nature of the business required to be done.

Whilst the wisdom of this State, in the furtherance of the enlargement of the Erie Canal, cannot be questioned, the extension of a like policy to unimportant branches would be deemed absurd; the first having been found too small for its business, whilst the latter are undoubtedly quite as large as can ever be required. The same reasoning applies with equal force to railroads; for whilst upon some roads a gauge of 6 ft. may be found more economical in the transaction of a *heavy business*, a gauge of 4 ft. 8½ in. may be much more suitable for the business of others; indeed it is questionable whether, for a road doing a very *light business*, even the latter may not be found too wide for economical transportation.

The question to be decided, therefore, in determining the proper width of gauge to be adopted on any given line of railway, is not whether a gauge of 6 ft. possesses greater capacity than a gauge of 4 ft. 8½ in., but rather what width of gauge is the best adapted to admit of such a construction of machinery as will most profitably overcome the resistances of the line, and that will meet the nature and extent of traffic, present and prospective.

Letter received from H. STANLEY GOODWIN, Esq., *Assistant General Superintendent of the Lehigh Valley Railroad, in relation to the character of power, loads hauled, and cars used, upon that road :*

LEHIGH VALLEY RAILROAD COMPANY,
OFFICE OF THE SUPERINTENDENT AND ENGINEER,
BETHLEHEM, PA., *July* 15, 1871.

S. SEYMOUR, Esq.,
No. 20 *Nassau Street,*
New York.

DEAR SIR,—Your favor of the 10th inst. is duly received and noted, asking certain questions which I will endeavor to answer.

The road engines most in use by us are of two kinds: first, the ordinary 10-wheel engine, weighing from 76,400 lbs. to 78,000 lbs., with fire and steam, of which from 61,-600 to 63,000 lbs. weight is on the 6 drivers, and the remainder upon the leading truck.

Some of these engines have drivers 4 ft. in diameter, and cylinders 17 × 24 ; others, drivers 4½ ft., and cylinders 18 × 22.

The other kind of engines, called "Consolidation," and built by ourselves, and by M. Baird & Co. from our original design, weigh 86,000 lbs. with fire and steam, of which 76,000 lbs. on drivers ; 8 drivers, 4 ft. diameter ; cylinders 20 × 24.

That portion of our road over which our heaviest traffic passes is between Mauch Chunk and Easton, a distance of 46 miles.

On this the grade descends in favor of the trade, varying from 0 to 20. ft. per mile, with many curves of 6° or 955 ft. radius.

The grade on this portion of the road is such that an engine can haul down with the same ease the number of loaded coal cars, weighing an average of $8\frac{8}{10}$ tons, that the same engine can haul up empty, weighing an average of $3\frac{4}{10}$ tons.

In summer, and in good weather, we haul with one of the 10-wheel engines 150 cars down, weighing 1,320 tons, and the same number up empty, weighing 510 tons.

We do not consider this the ultimate capacity of the engines, but as nearly so as it is safe, prudent, and economical to go. We have at times, by chance or design, taken as many as 200 cars both up and down.

We do not run the "Consolidation" engines on this part of the road, or if we do, we do not give them more than 200 cars, and seldom so many, although we have taken with them as many as 250, and could probably exceed 300 before reaching the engine's capacity.

We have at one place 12 miles of grade, averaging 96 ft. per mile against the trade, with curves of 6°. Up this grade we haul with 10-wheel engines 22 loaded cars, weighing $8.8 \times 22 = 194$ tons, and with "Consolidations," 33 loaded cars, weighing $8.8 \times 33 = 290$ tons.

On a grade of 146 ft. per mile for 2 miles, we haul with 10-wheel engines 37 empty cars = 122 tons, and with "Consolidations" 55 cars = 182 tons.

We have also grades of 40, 60, and 132 ft. per mile, but perhaps the above instances will be sufficient for your purpose.

We shall be glad to give you any further information you desire; and if you should wish to observe for yourself the working of our road and engines, we shall be happy to furnish you every facility.

Very truly yours,

H. STANLEY GOODWIN,
Assist. Genl. Superintendent.